

Growth and Yield 32 Years after Commercially Thinning 56-year-old Western Hemlock

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ABSTRACT

Remeasurement data and observations over a period of 32 years from twenty 0.1619-ha permanent plots on East Thurlow Island, British Columbia, suggest that commercially thinning dense, good-site, 56-year-old (30 m tall) western hemlock stands neither appreciably increases cumulative yield nor has a significant impact on stand dynamics. Compared to unthinned stands, the commercially thinned stands had:

- virtually the same top height, and total volume gross growth and gross production;
- up to 8% more potentially usable total volume yield (including thinnings), but up to 26% less total volume at final harvest age 88; and
- virtually the same crop-tree (247 largest-diameter trees per hectare) quadratic mean diameter, but up to 14% larger entire-stand quadratic mean diameter.

There was no clear relationship between cumulative yield and thinning intensity. These results show that the commercial thinning slightly increased total stand yield (including thinnings) and produced stands of larger average diameter at rotation age 88, but that it also reduced usable total volume at final harvest and had virtually no effect on size of the crop trees. The decision to do a late commercial thinning in dense, unmanaged western hemlock stands in coastal British Columbia is, therefore, largely an accounting one: whether or not to harvest part of the stand earlier, mostly at the expense of the yield otherwise available for final harvest.

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INTRODUCTION

Commercial thinning — rarely practised in British Columbia, mainly because of the abundance of old-growth forests and a lack of suitable second-growth stands — has recently become of greater interest to forest managers. Not only can it increase value and net revenue from forests by making wood available early, it can also produce larger trees at rotation. As well, it can increase employment and help overcome wood supply problems. The potential magnitude of these benefits varies with the thinning regimes adopted, prevailing market conditions, and stand history. However, it is doubtful that commercial thinning can result in an appreciable increase in cumulative yield or have a significant impact on stand dynamics.

Studies of commercial thinning of western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) published in the Pacific Northwest (Staeble 1957; Warrack 1960; Wiley 1968; Farr and Harris 1971; Hilt *et al.* 1977; Graham *et al.* 1985) suggest that the thinning improves, to varying extents, the growth of residual trees, but that it produces no consistent growth and yield responses related to thinning intensity. This report documents growth and yield following four levels of single-entry commercial thinning (ranging in intensity from light to heavy) in a 56-year-old coastal western hemlock stand on a good site in the Coastal Western Hemlock Vancouver Island Drier Maritime (CWHa1) variant (Klinka *et al.* 1984) on East Thurlow Island, B.C. It is based on 32-year remeasurements and observations from B.C. Ministry of Forests and Lands Research Branch Experimental Project (EP) 388, one of two old, well-designed but infrequently measured commercial thinning studies in coastal British Columbia.¹

METHODOLOGY

Study Area

Experimental Project 388 was established in 1953 by the B.C. Forest Service in a western hemlock stand of age 56 years, top height 30 m, and density 1400-1500 stems per hectare. It is located on East Thurlow Island, which is roughly 50 km north of Campbell River (Figure 1). The study was to determine growth response and potential (utilization) and profit from thinning immature western hemlock stands.² The study area was 40 acres (16.2 ha) of a fairly uniform, well-stocked 56-year-old stand of 90% western hemlock (by volume) and 10% Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and western redcedar (*Thuja plicata* Donn.). The stand originated from natural regeneration following clearfelling of old growth in 1894 and hot slashburning in 1896, making it one of the oldest second-growth western hemlock stands in the province. The western hemlock site index ranges from 30 to 34 m at 50 years breast-height age, based on Wiley's (1978) site curves.

Study Design and Treatments

The study was a randomized complete block design with five thinning treatments (including a control), each replicated four times (Figure 1). The treatments were defined in terms of residual basal area (Table 1). Each replicate was a square, 0.4 acre (0.1619 ha) plot. The 10- to 20-m wide buffer strips between adjacent plots and the surrounding areas were thinned to 52 m²/ha. The plots were blocked by initial (pre-thinning) basal area, which showed clear differences among the plots over a range from 51 to 67 m²/ha (Table 1). In general, there was little variation in initial stand attributes among plots within blocks (Table 2).

¹ The other study, EP 364, commercial thinning of Douglas-fir, has been reported by Omule (1988) based on 35-year remeasurements and observations.

² Joergensen, C. 1953. Working plan for experiment 388. Commercial thinning (western hemlock). EP 388 File Report. B.C. Min. For. Lands, Res. Branch, Victoria, B.C.

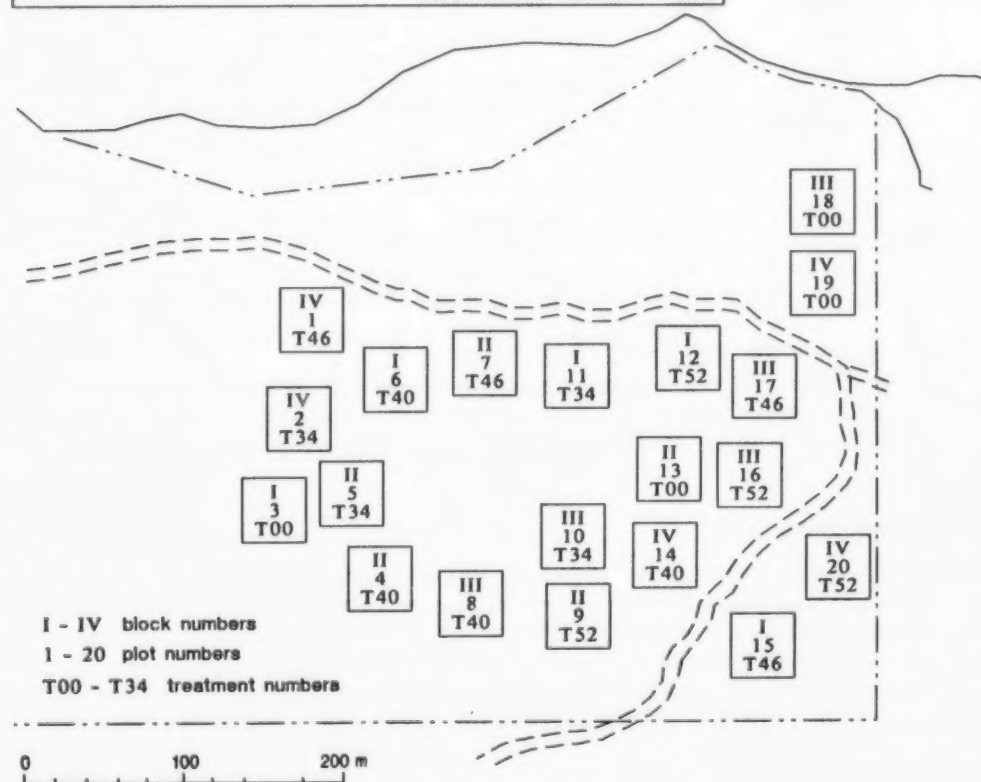
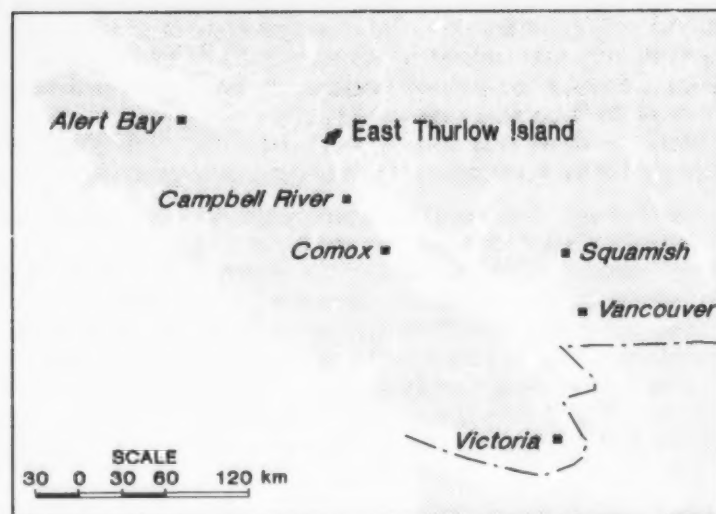


FIGURE 1. EP 388 study area and plot layout.

TABLE 1. Treatment codes and definitions

Treatment Code	Plot pre-treatment basal area (m ² /ha)				Actual residual plot basal area (m ² /ha)						Planned residual basal area (m ² /ha)
	Block				Block				Average		
	I	II	III	IV	I	II	III	IV	(m ² /ha)	(% of Initial)	
C62	55.9	61.3	64.8	63.9	55.9	61.3	64.8	63.9	61.5	100	unthinned
T52	59.0	60.4	65.6	67.4	54.9	50.8	54.2	52.1	53.0	84	52
T46	54.1	60.4	65.2	63.8	48.6	46.1	44.9	45.6	46.3	76	46
T40	55.2	60.4	65.3	65.5	41.2	42.4	41.1	43.1	41.9	67	40
T34	56.4	63.6	62.5	65.5	35.1	36.0	35.8	33.9	35.2	57	34
Average	56.1	61.9	64.7	65.2							

TABLE 2. Pre-treatment stand attributes

Attribute	Block ^a			
	I	II	III	IV
Basal area (m ² /ha)	56.1(3) ^b	61.9(3)	64.7(2)	65.2(2)
Stem count (/ha)	1400(10)	1438(10)	1510(4)	1429(13)
Quad. diameter (cm)	22.6	23.4	23.4	24.1
Total height ^c (m)	30.2(4)	29.0(3)	29.5(4)	30.0(4)

^a Plots were blocked by basal area per hectare.

^b The values in brackets are coefficients of variation (%) based on five plots.

^c Average height of dominants and co-dominants.

TABLE 3. EP 388 plot remeasurement and treatment

Date (month/year)	Measurement ^a		Treatment
	Total age (yr)	Plot Nos.	
7/1953 ^b	55	1-20	
6-10/1954	56	1-3,6,7,11-13,18,19	Commercial thinning; d/D = 0.85 (plots 1, 2, 6, 7, 11-12)
11/1955	57	4,5,8-10,14-17,20	Thinning to waste; d/D = 0.85
7/1959	61	1-20	
8/1982	84	1-20	
3/1987	88	1-20	

^a All plot trees were measured for diameter at breast height (4.5 ft; 1.37 m); a subsample was measured for total height. Imperial measurements made prior to 1982 were converted to metric before analysis.

^b Pre-treatment measurement.

Half of the 20 plots were thinned at age 56, and the remainder at age 57. All the plots were measured at 4- to 23-year intervals between ages 55 and 88, including before thinning (Table 3). The thinnings ranged from very light (Treatment T52) to heavy (Treatment T34), removing an average of 14-41% of original total volume, with a planned d/D ratio of 0.85 (Table 4). (Diameter distributions of thinnings and of the stands before thinning were not available.) Skidtrails and landings were located outside the plots. The age 56 thinnings were extracted by a rubber-tired 40-horsepower tractor and sold. However, because of a lack of markets, the age 57 thinnings were left on site. No differences existed in thinning criteria between the plots where thinning was to waste and those where logs were extracted. The plots were once abandoned during the 23-year period between ages 61 and 84 because of difficult access.

Analysis

The growth and yield effects of commercially thinning coastal western hemlock stands were examined based on the 20 sample plots. Graphically compared were: cumulative mortality; standing yield; cumulative yield (including thinnings); gross production to age 88; and gross periodic growth (over the 32-year period) of the thinned and unthinned stands, on the basis of the usual stand attributes.

Entire-stand and crop-tree average and per-hectare values of top height, quadratic mean dbh, stem count, basal area, and total and merchantable volume were obtained from individual tree measurements for each plot and period of measurement. Summaries of crop trees — defined as the most valuable trees at final harvest — were obtained by tracing back the growth of 40 trees per 0.1619-ha plot (247 trees per hectare) that were the largest by dbh at age 88. Top height was calculated as the average height (measured or estimated from a height-diameter curve) of the 100 largest-diameter trees per hectare (as estimated by the 16 largest western hemlock trees per 0.1619-ha plot). Quadratic mean dbh is the diameter at breast height, outside bark, of the tree with mean basal area. Total volume is whole stem, inside bark, estimated from volume tables (B.C. Forest Service 1976; Godfrey³). Merchantable volume is the total volume between a 30-cm stump and a 10-cm diameter inside bark top, estimated from merchantable volume factors (B.C. Forest Service 1976; Godfrey⁴).

There were apparent differences in initial stand values among treatments (Table 4). For example, differences among treatments in average height of dominants and co-dominants were up to 1.3 m before thinning. Thus, treatment means for each stand attribute were adjusted based on analysis of covariance with site index and the corresponding stand attribute's initial value as covariates.⁵ Adjusted tree count was calculated based on adjusted quadratic mean dbh and adjusted basal area. The values of cumulative mortality were also adjusted, but those of the thinnings were not. In the rest of the report, treatment "means" will refer to "adjusted means," unless otherwise specified.

Standing yield (= means of live trees at age 88), cumulative yield (= standing yield + thinnings), cumulative mortality over the 32-year period, and gross production (= cumulative yield + cumulative mortality) were calculated in terms of basal area per hectare and total and merchantable volumes per hectare, and plotted for the thinned and unthinned stands.

Gross periodic growth in quadratic mean dbh, top height, basal area, and total and merchantable volume were calculated as the difference between the attribute's mean for standing trees at beginning of a growth period and the attribute's mean for all trees at the end of the period. These values were plotted for thinned and unthinned stands by measurement interval.

As well, stem count per hectare, relative density = $BA/\sqrt{dbhq}$ (where BA = stand basal area and dbhq is diameter of average basal area tree; Curtis 1982), and diameter distributions were plotted to illustrate the effects of thinning on stand development.

³ Godfrey, G. 1985. Personal communication. B.C. Min. For., Res. Branch, Victoria, B.C.

⁴ Godfrey, G. 1983. Merchantable volume factors (MVF) for immature trees. Smoothing out the steps. B.C. Min. For., Res. Branch, Victoria, B.C. Unpubl. memo, dated 1983-10-27. File EP 703.

⁵ Adjusted means, calculated using SAS (SAS Institute, Inc. 1985, pp. 246-248), take into account the possible confounding effect of different initial stand values and site quality in the thinned and unthinned plots.

TABLE 4. Stand attributes before and after thinnings

Attribute	Before thinning ^a					Thinnings ^b				After thinning ^b				
	C62	T52	T46	T40	T34	T52	T46	T40	T34	C62	T52	T46	T40	T34
Stem count (/ha)	1501	1481	1487	1409	1402	388	523	700	837	1501	1093	964	709	565
Basal area (m ² /ha)	61.5	63.1	60.9	61.8	62.0	10.1	14.6	20.6	26.8	61.5	53.0	46.3	41.2	35.2
Av. height (all trees)						24.2	23.3	24.6	24.8					
Av. top height (m)										33.0	32.4	32.7	32.7	33.6
Av. ht ^c	30.0	29.3	29.3	29.6	30.3									
Av. quad. diam (cm)	22.8	23.3	22.8	23.6	23.7	18.2	18.9	19.4	20.2	22.8	24.8	24.7	27.2	28.2
d/D ratio ^d						.78	.83	.82	.85					
Volume (m ³ /ha)	787.2	795.7	755.4	786.2	813.8	113.0	155.9	230.7	331.7	787.2	682.7	599.5	555.5	482.1
% volume cut (%)						14.2	20.6	29.3	40.8					
% basal area cut (%)						16.0	24.0	33.3	43.2					

^a Measurements done between 7/1953 - 8/1954 (ages 55 and 56); assume meas. age before thinning = 55.

^b Measurements done between 6/1954 - 11/1955 (ages 56 and 57); assume meas. age after thinning = 56.

^c Average height of dominant and co-dominants; data available for "before thinning", but only in summary form.

^d The planned (target) d/D was 0.85 (d = average diameter of thinnings; D = stand diameter before thinning). Percent live crown was about 38%.

RESULTS AND DISCUSSION

The effects of commercial thinning on mortality and on stand growth and yield are briefly discussed below. Readers interested primarily in volume mortality and yield summaries can proceed directly to Table 5 and Figure 2, noting that salient findings are summarized in the Conclusions section.

Mortality

Generally, mortality in the thinned stands was much less than that in the unthinned. Over the 32-year period, the unthinned stands lost 50% of the initial stems, whereas the thinned stands lost only 20-34% (Table 6). That is, the percent of initial stem number lost to mortality in the thinned stands on the average was 32-60% of that lost in the unthinned, suggesting that thinning probably removed many trees that would have died, and allowed some trees to survive that would have otherwise died.

Distribution of mortality over time by treatment was irregular. However, cumulative basal area and number of trees lost to mortality were greater in the less heavily thinned stands, unlike volume losses which were more erratic (Table 6). Average dbh of trees that died increased with increase in thinning intensity, especially on T34.

Growth and Yield

Height

Top height and top height growth were probably not affected by the commercial thinning. The average top height at age 88 in the thinned and unthinned stands was 42.2 m. The periodic growth over the 32-year period averaged 9.3 m. The treatment average top height/age profiles were slightly different in shape from those defined by Wiley's (1978) site curves (Figure 3).

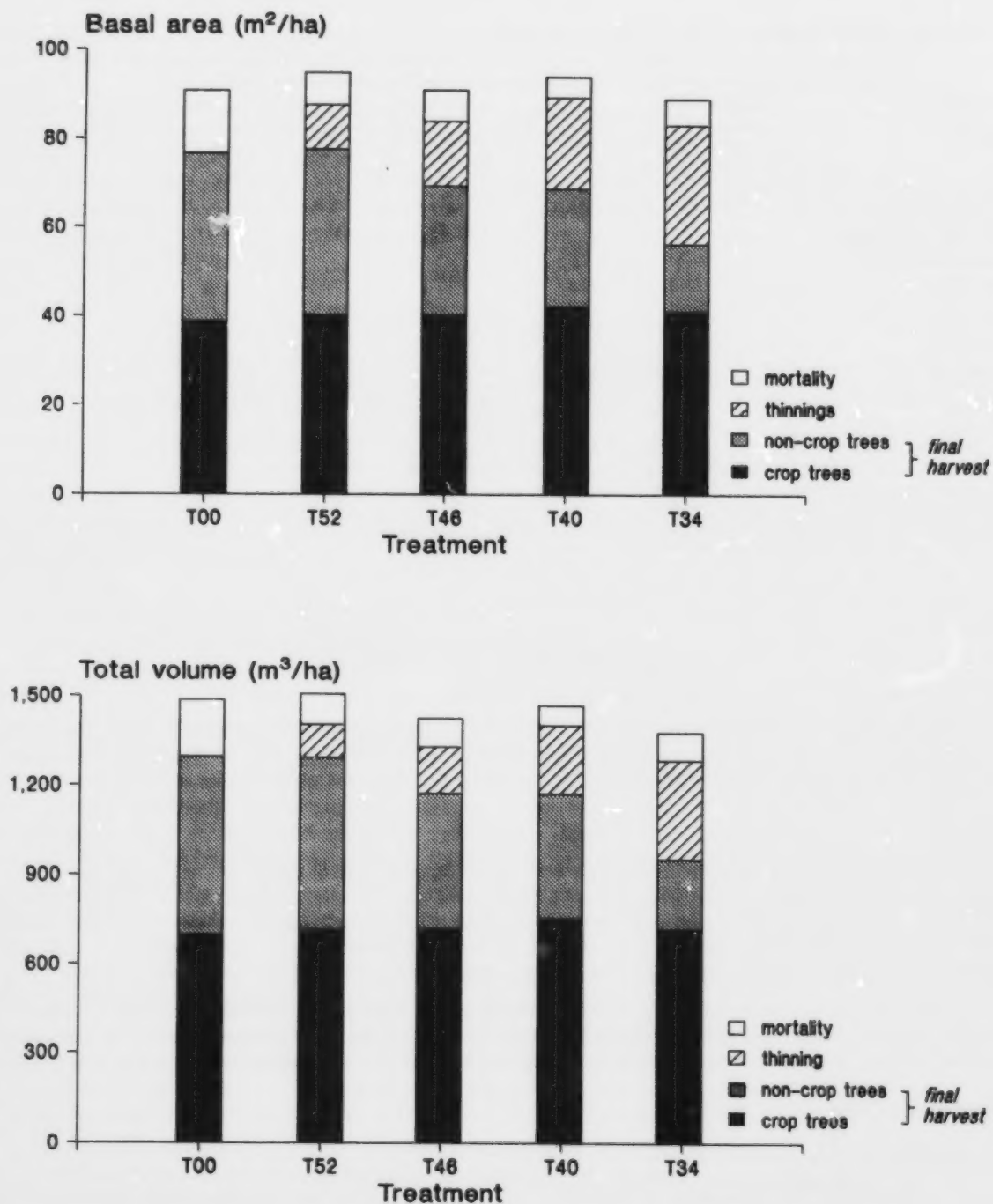


FIGURE 2. Cumulative thinnings, mortality, yield, and gross production of thinned and unthinned stands. The average dbh of thinnings and mortality are given in Tables 4 and 6, respectively. Crop trees are defined as the most valuable trees at final harvest (247 largest-diameter trees per hectare).

TABLE 5. A summary of attributes of standing trees at age 88^a

Attribute	Unthinned stands	Thinned stands			
	C52	T52	T46	T40	T34
Entire stand					
Stem count (/ha) ^b	745	722	625	567	451
Average diameter ^c (cm)	36.2	37.0	37.6	39.3	39.9
Top height ^d (m)	42.2	42.1	42.6	42.0	42.0
Basal area (m ² /ha)	76.7	77.6	69.4	68.8	56.4
Total volume (m ³ /ha)					
- all trees	1297.2	1292.9	1176.5	1174.5	956.7
- trees 42.5 cm dbh	1050.7	1060.2	953.0	1068.8	889.7
Crop trees ^e : - age 88					
Average diameter (cm)	44.9	45.7	45.6	46.9	46.0
Basal area (m ² /ha)	39.1	40.5	40.5	42.6	41.4
Total volume (m ³ /ha)	720.9	720.2	723.6	759.7	723.6
Merch. volume (m ³ /ha)	676.1	693.2	696.5	731.0	696.2
Crop trees: - age 56					
Average diameter (cm)	33.8	33.4	32.7	34.4	33.6
Basal area (m ² /ha)	22.2	21.7	20.7	23.0	21.9
Total volume (m ³ /ha)	311.9	298.2	288.1	320.2	310.9

^a The summaries are adjusted means based on four plots per treatment; age 56 values for the entire stand are provided in Table 4.

^b Stem count based on adjusted basal area and adjusted quadratic mean dbh.

^c Quadratic mean diameter at breast height, outside bark.

^d Average height of 100 largest-diameter trees per hectare (estimated from 16 largest-diameter trees per 0.1619-ha plot).

^e The most valuable trees at final harvest: 40 largest-diameter trees per 0.1619-ha plot (or 247 trees per hectare).

TABLE 6. Mortality per unit area in thinned and unthinned stands

Treatment Code	Cumulative mortality (age 56-88)				
	Stem count		Basal area (m ² /ha)	Quad. mean dbh (cm)	Total volume (m ³ /ha)
	(/ha)	(% of initial)			
C62	756	50	14.1	15.4	192.3
T52	371	34	7.9	16.5	109.8
T46	339	35	9.1	18.5	127.5
T40	142	20	3.4	17.5	49.8
T34	114	20	4.3	21.9	64.5

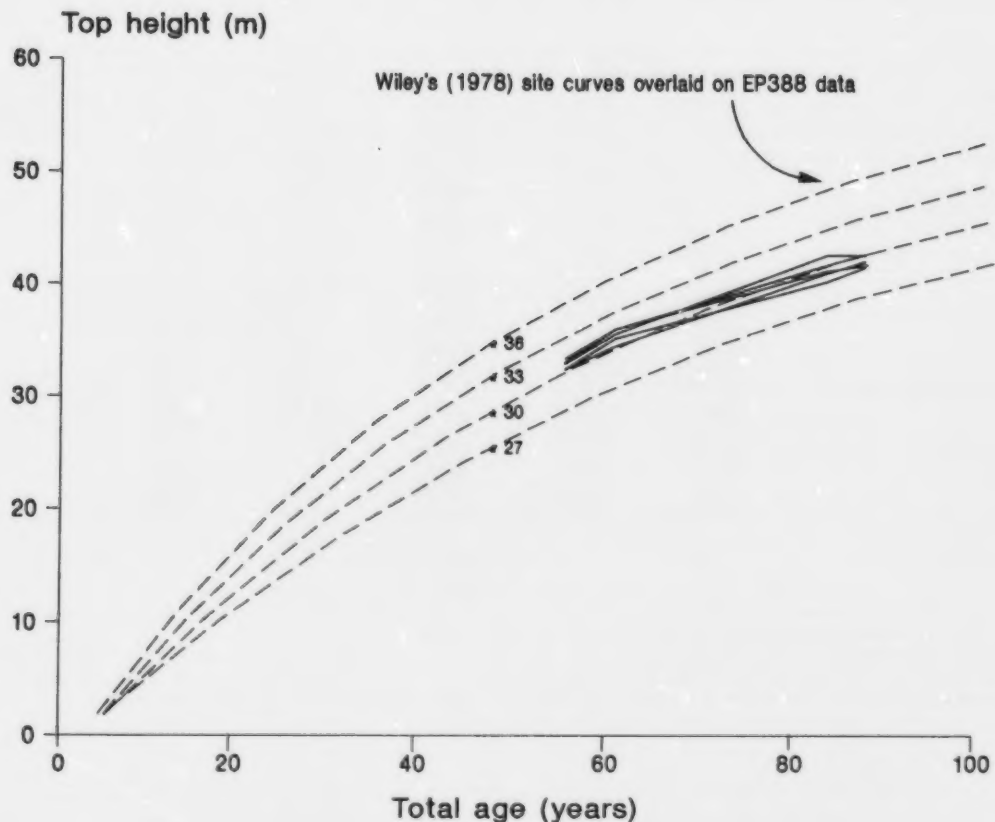


FIGURE 3. Top height/age profiles by treatment.

Diameter

Attained stand diameter was higher in the thinned than in the unthinned stands. At age 88 the entire-stand quadratic mean dbh in the unthinned stands was 36.2 cm, and in the thinned stands it was 37.0, 37.6, 39.3, and 39.9 cm for treatments T52, T46, T40, and T34, respectively. However, the crop-tree quadratic mean dbh was virtually the same in the thinned and unthinned stands — 45.0, 45.7, 45.6, 46.9, and 46.0 cm for treatments C62, T52, T46, T40, and T34, respectively. Treatment average diameter distributions for the entire stand were different, whereas those for the crop trees were virtually similar among treatments (Figure 4). Over the 32-year period, and excluding the arithmetic increase due to trees cut in the thinning (Figure 5), quadratic mean dbh in the thinned stands increased by 12.2, 12.9, 12.1, and 11.7 cm for treatments T52, T46, T40, and T34, respectively. The increase averaged 13.4 cm on the unthinned plots. The 0.5- to 1.7-cm difference in increase in dbh between unthinned and thinned stands represents a combination of the actual growth of comparable trees in the thinned relative to the unthinned stands, slower growth on the many more small trees present in the unthinned stands, and the arithmetic increase due to loss of smaller-than-average trees to mortality in the unthinned stands (Omule 1988). Crop-tree quadratic mean dbh increased by 11.1, 12.3, 12.9, 12.5, and 12.4 cm for treatments C62, T52, T46, T40, and T34, respectively, over the same period (Table 5).

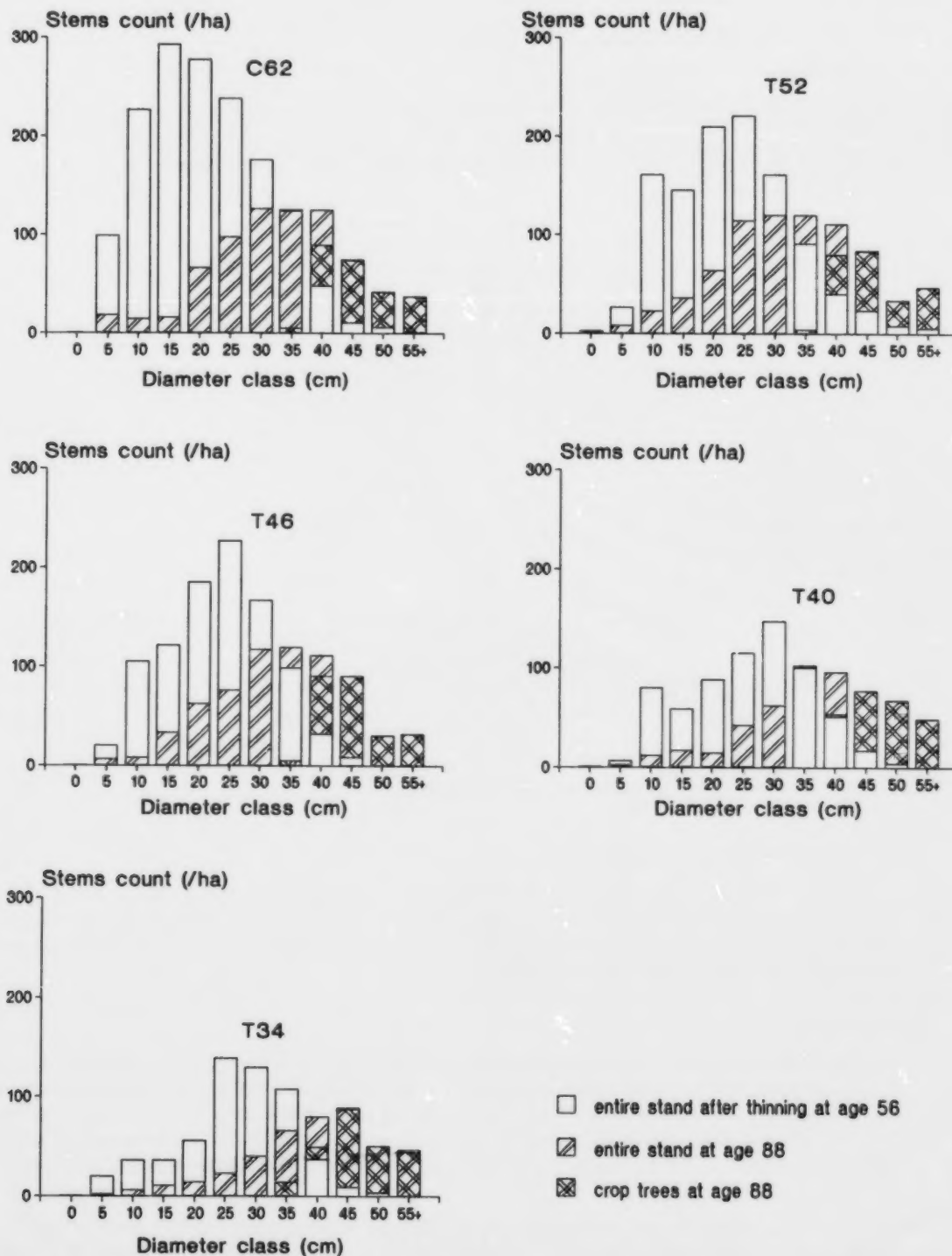


FIGURE 4. Average entire-stand and crop-tree diameter distributions after the age 56/57 thinning and at age 88. Crop trees are defined as the most valuable trees at final harvest (247 largest-diameter trees per hectare).

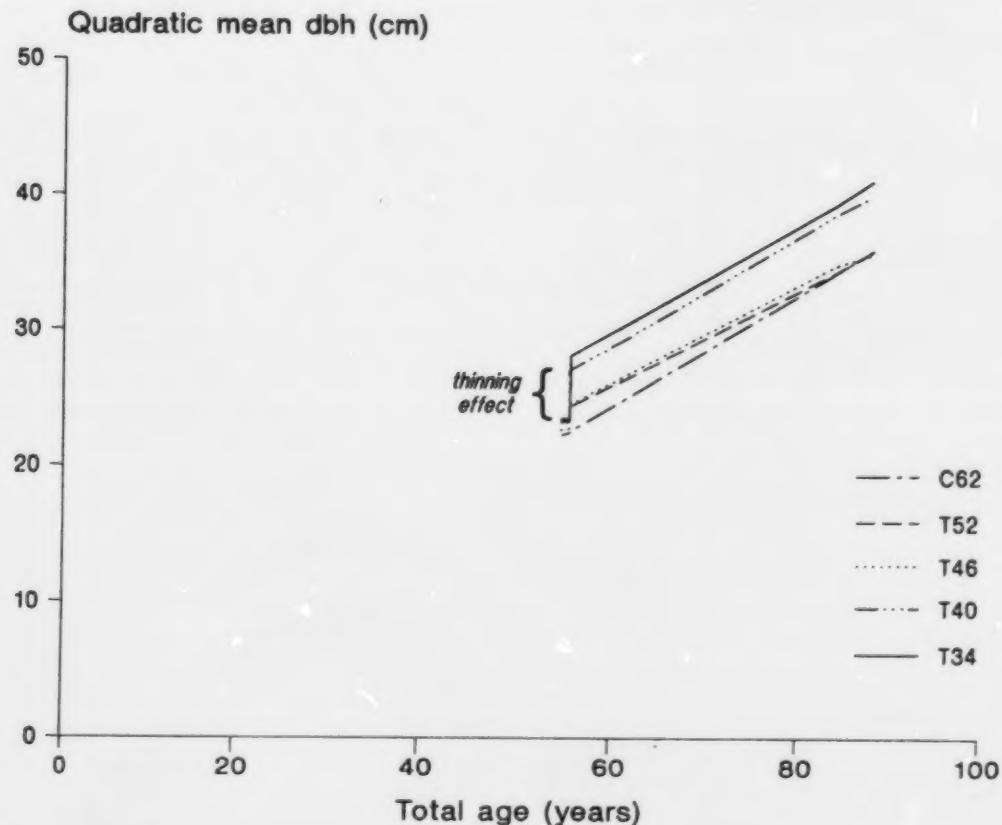


FIGURE 5. Stand diameter development of thinned and unthinned stands.

Relative density

Relative density (Curtis 1982) in the unthinned stands was virtually constant at about 13 (metric units) from age 56 to 88, whereas in the thinned stands it is rebounding after a sharp drop owing to the age 56/57 thinning (Figure 6). However, because of the 23-year gap in measurements, it is uncertain how high relative density went between ages 61 and 84.

Basal area

The thinning reduced residual basal areas to 57-84% of that in a comparable unthinned stand (Table 1). Gross growth in the 5-year period immediately after thinning was higher in the unthinned stands than the thinned, with the more heavily thinned stands having much lower growth. Since that time, however, gross growth over the 23-year and 4-year periods in the thinned stands has, on the average, equalled or slightly exceeded that in the unthinned, despite lower levels of growing stock in the thinned stands (Figure 7).

The basal areas of standing trees at age 88, plus the thinnings, were 8-17% greater in the thinned stands than in the unthinned (Figure 8). The cumulative basal area yields to age 88 were 76.7, 87.6, 84.0, 89.4, and 83.2 m²/ha in treatments C62, T52, T46, T40, and T34, respectively. The relationship between cumulative yield and thinning intensity is unclear, although it is probably confounded by the differences among treatments in residual stand structure after thinning.

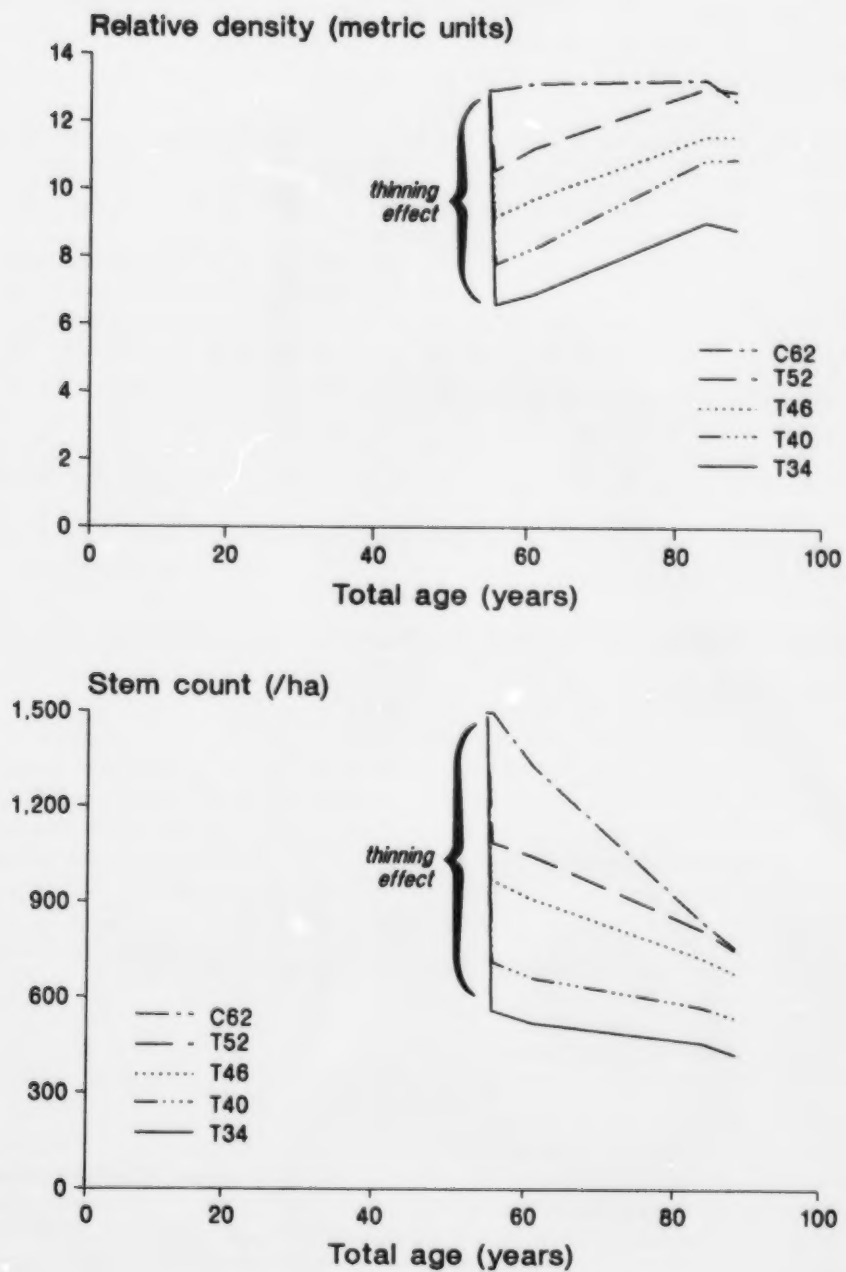


FIGURE 6. Development of stem count and relative density (Curtis 1982) in thinned and unthinned stands.

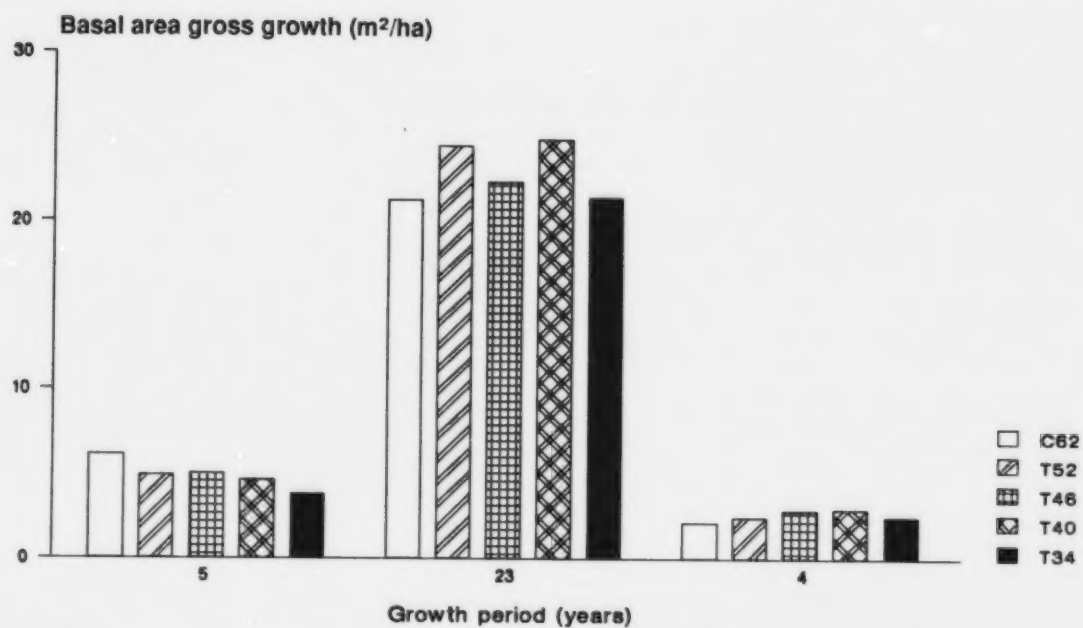


FIGURE 7. Periodic growth in basal area per hectare.

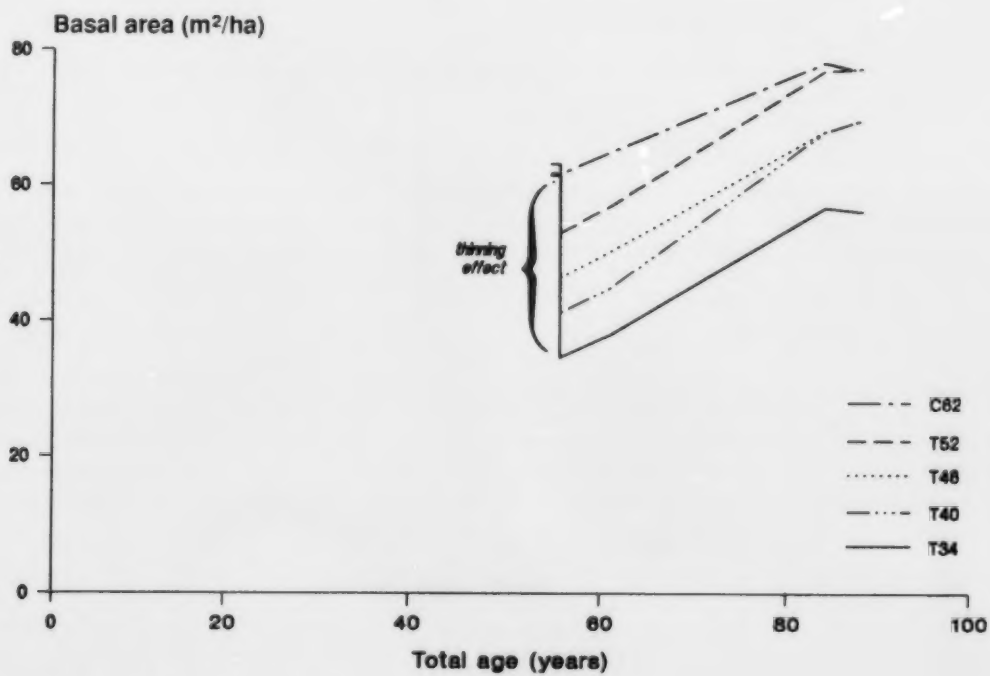


FIGURE 8. Curves showing basal area over age for thinned and unthinned stands.

At a final-harvest age of 88 years, the basal area available in the unthinned stands was higher than in the thinned by up to 20.3 m²/ha (26%) (Table 5). Gross production was virtually the same in thinned and unthinned stands — 89-95 m²/ha (Figure 2). Thus, as expected, commercial thinning has provided an earlier harvest of part of the stand and recovered impending mortality to varying extents, but reduced final harvest basal area.

Total volume

The growth and yield trends among treatments in terms of total volume were generally similar to those found for basal area.

Total volume mean annual increment (m.a.i.) is lower in the thinned stands than in the unthinned, but at ages 51-88 none of the stands appear to have yet reached a maximum m.a.i. (Figure 9). Gross growth in the 5-year period immediately after thinning was higher in the unthinned stands than the thinned, with the more heavily thinned stands having much lower growth (Figure 10). Since that time, however, gross growth over the 23-year and 4-year periods in the thinned stands has, on the average, equalled or slightly exceeded that in the unthinned, despite lower levels of growing stock in the thinned stands (Figure 10).

The total volume available for final harvest at age 88 was higher in the unthinned stands than in the thinned by up to 36% (Table 5). About 81, 82, 81, 91, and 93% of the total volume at final harvest resided in the 42.5-cm or larger trees in treatments C62, T52, T46, T40, and T34, respectively. The cumulative total volume yields to age 88 were 1297.2, 1405.9, 1332.4, 1405.2, and 1288.4 m³/ha for treatments C62, T52, T46, T40, and T34, respectively. That is, the thinned stands produced up to 8% more potentially usable total volume to age 88 than did the unthinned stands (Figure 2). The relationship between cumulative yield and thinning intensity was unclear, although it was probably confounded by treatment differences in residual (post-thinning) stand structure.

Gross production was virtually the same in the thinned and unthinned stands — 1382-1488 m³/ha (Figure 2).

Merchantable volume

The results for merchantable volume, the total volume between a 30-cm high stump and a 10-cm diameter inside bark top, were virtually the same as those for total volume. The merchantable volume available for harvest at age 88 was up to 26% higher in the unthinned than in the thinned stands. Cumulative merchantable volume yield was 1242, 1344, 1274, 1372, and 1271 m³/ha in treatments C62, T52, T46, T40, and T34, respectively (Table 5).

SILVICULTURAL OPPORTUNITIES

The results in this study have important implications for the management of western hemlock stands in coastal British Columbia, even though the commercial thinning regimes were not designed for today's economy.

Benefits of late commercial thinning of dense, unmanaged western hemlock stands are limited to economic and harvest scheduling opportunities. The study results suggest that commercially thinning dense (Curtis' [1982] relative density: 13 metric units) western hemlock stands on good sites (Wiley's [1978] site index: 30-34 m at 50 years breast-height age) at a top height of 30 m, has no appreciable effect on stand gross growth or cumulative yield. Moreover, in practice, final yield can be reduced by commercial thinning because of skidtrails and landings. (Most commercial thinnings reduce yields to the extent that the skidtrails and landings reduce stocking.⁶) The decision to thin these or similar stands is, therefore, largely an accounting one: whether or not to harvest part of the stand earlier, mostly at the expense of the yield otherwise available for final harvest.

⁶ J.H.G. Smith. Personal correspondence. January 29, 1988. On file EP 388, B.C. Min. For. Lands, Res. Branch, Victoria, B.C.

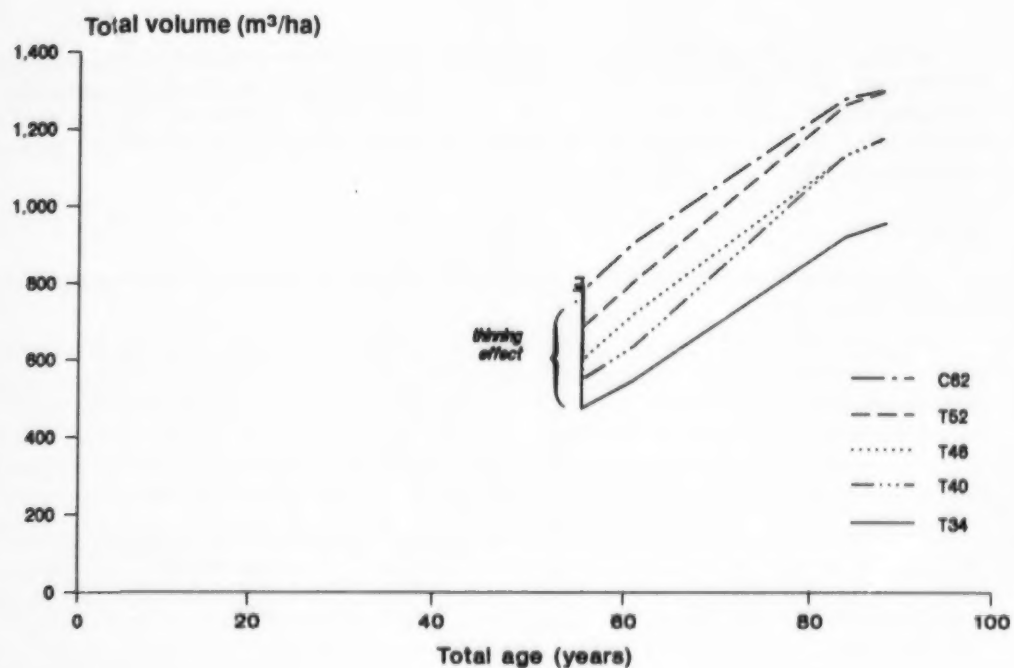


FIGURE 9. Curves showing total volume over age for thinned and unthinned stands.

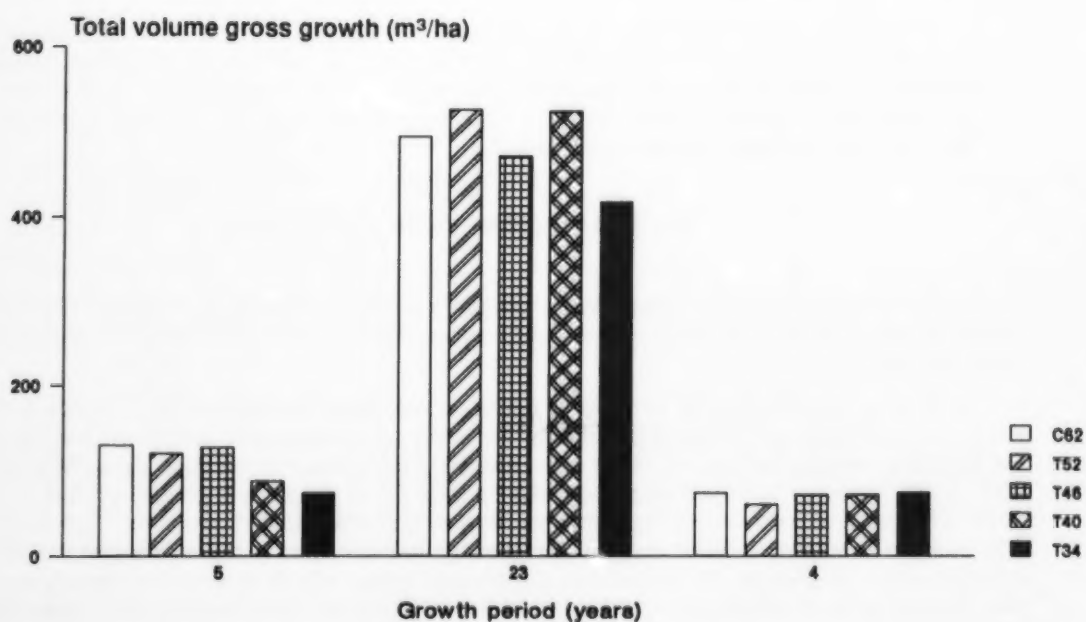


FIGURE 10. Periodic growth in total volume per hectare.

Additional gains could possibly be realized through early density control. Western hemlock's rapid growth and ability to respond to increased light can assure significant growth response following early stocking control (Hoyer and Swanzy 1986, p. 2).

Compared to the Douglas-fir yields reported by Omule (1988), the gain in cumulative yield through late commercial thinning of western hemlock (Treatment T34) were slightly less (Table 7). Thus, it might be less favourable to conduct a late, heavy commercial thinning in a dense, unmanaged western hemlock stand than in a comparable Douglas-fir stand.

TABLE 7. Comparison of yields of western hemlock and Douglas-fir

Attributes	Species	
	Douglas-fir ^a	Western hemlock (T34)
Thinned stand characteristics		
Total age (yrs)	51	56
Top height (m)	35	30
Relative density (metric units) ^b	10	13
Thinning characteristics		
d/D ratio	0.99	0.85
% volume removed ^c	43	43
Thinning gains (% of unthinned) ^d		
Cumulative mortality (m ³ /ha)	36	34
Cumulative basal area yield (m ² /ha)	20	9
Cumulative volume yield (m ³ /ha)	12	0
Crop-tree diameter (cm) ^e	3	2

^a Source: Omule (1988).

^b Curtis' (1982) relative density index.

^c Douglas-fir was thinned a second time at age 69, removing 10% volume.

^d Douglas-fir gains were at age 86, 35 years after initial thinning.

^e Number of crop trees were 196 and 247 stems per hectare for Douglas-fir and western hemlock, respectively.

CONCLUSIONS

For the range of site, stand, and treatment conditions in this study, the results indicate that:

- The thinning had no important effect on top height, and total volume gross growth and gross production.
- Varying with thinning intensity, the thinned stands produced up to 8% more cumulative total volume (including thinnings) to age 88 than did the unthinned stands. However, there was no clear relationship between cumulative yield and thinning intensity.
- At a rotation age of 88 years, the unthinned stands had up to 26% more total volume available for final harvest than did the unthinned stands.
- Although the entire-stand quadratic mean dbh was up to 14% larger in the thinned than in the unthinned stands, crop-tree quadratic mean dbh was about the same in the thinned and unthinned stands at age 88.

This study suggests that the commercial thinning of dense, unmanaged coastal western hemlock stands results in marginally more cumulative volume yield over the rotation, and in stands of larger average diameter — but also of lower total volume — at final harvest. The importance of these effects in deciding whether to thin or not depends upon several other factors, such as the economics of the commercial thinning (frequency, grade, and timing), and stand history and conditions; as well as on the need to create employment and alleviate local timber supply problems. The growth and yield data collected and the actual growth response values obtained to date may be useful for validating growth models such as TASS (Mitchell 1975), and for constructing and comparing managed stand yield tables for various commercial thinning regimes.

REFERENCES

- B.C. Forest Service. 1976. Whole stem cubic meter volume equations and tables. Centimeter diameter class merchantable volume factors. B.C. Min. For. Lands, Victoria, B.C.
- Curtis, R.O. 1982. A simple index of stand density for Douglas-fir. *For.Sci.* 28:92-94.
- Farr, W.A., and A.S. Harris. 1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Res. Pap. PNW-124.
- Graham, J.N., J.F. Bell, and F.R. Herman. 1985. Response of Sitka spruce and western hemlock to commercial thinning. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Res. Pap. PNW-334.
- Hilt, D.E., F.R. Herman, and J.F. Bell. 1977. A test of commercial thinning on the Hemlock Experimental Forest. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Res. Pap. PNW-225.
- Hoyer, G.E., and J.D. Swanzy. 1986. Growth and yield of western hemlock in the Pacific Northwest following thinning near the time of initial crown closing. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Res. Pap. PNW-365.
- Klinka, K., R.N. Green, P.J. Courtin, and F.E. Nuzsdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. B.C. Min. For. Lands, Land Manage. Rep. No. 25.
- Mitchell, K.J. 1975. Dynamics and simulated yield of Douglas-fir. *For. Sci. Monogr.* No. 17.
- Omule, S.A.Y. [1988]. Growth and yield 35 years after commercially thinning 50-year-old Douglas-fir. B.C. Min. For. Lands - FRDA Report. In press.
- SAS Institute Inc. 1982. SAS/STAT guide for personal computers, version 6 Edition. SAS Institute Inc., Box 8000, Cary, N. C. 27511-8000.
- Staebler, G.R. 1957. Early effect of two successive thinnings in western hemlock. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Res. Note 146.
- Warrack, G.C. 1960. Commercial thinning of western hemlock, East Thurlow Island, B.C. *For. Res. Review* (1960):45.
- Wiley, K.N. 1968. Thinning of western hemlock: a literature review. Weyerhaeuser For. Pap. 12, Weyerhaeuser Forestry Research Cent., Centralia, Wash. 98531.
- _____. 1978. Site index tables for western hemlock in the Pacific Northwest. Weyerhaeuser For. Pap. 17. Weyerhaeuser Forestry Research Cent., Centralia, Wash. 98531.